SEEING THE FORESTS FOR MORE THAN THE TREES

In March 1957, health officials in India feared a severe outbreak of yellow fever when reports from the Shimoga district described mass mortality among two types of monkeys. A team of researchers traveled to the state of Karnataka to investigate the reports. They found not yellow fever, but a prolonged and feverish illness among villagers that led to death in 5% of the cases. The cause was soon identified as a new virus, isolated from the *Haemaphysalis* species of tick, and traced to ticks found on the dead monkeys. The origins of the illness, named Kyasanur Forest disease, were ultimately traced back to the clearance of native evergreen forests, an influx of people and cattle, and the spread of thickets of an immigrant brush species in the newly opened areas. Ticks carrying the Kyasanur virus abounded on the small mammals and birds that settled in those thickets, and adapted to the humans that came to collect wood and other forest produce. In its peak year, 1983, the disease infected 1,555 people and claimed 180 lives.

Kyasanur Forest disease may have been the first infectious disease linked to deforestation, but it was not to be the last. In recent years, a growing body of investigative research has linked changes in forest cover to a number of diseases, including several previously thought to be controlled.

Deforestation's role in the global increase in infectious disease may be its most direct health impact, but it's not the only one. In the longer-term, the intentional cutting or burning of natural forests involves losses of potential medicines and more pollutants in air and water. Deforestation also contributes to global climate change and its expected adverse effects on health

Cause and Effect

Assessing the health effects of deforestation is difficult because of the breathtaking speed at which the world's forests are disappearing. At last June's review by the United Nations of progress toward meeting the goals set at the 1992 Earth Summit (*EHP* 105:694–695), the issue of deforestation was examined from many angles. Between 1980 and 1990, about 15.4 million hectares (ha) of tropical forests and woodlands fell to human uses each year, according to the Food and Agriculture Organization (FAO) of the United Nations. From 1990 to 1995, the world lost another 56 million ha of forest cover, an area nearly twice the size of Italy.

The best-known causes of deforestation are human population growth and clearance for agricultural production, but another is the steadily growing global demand for wood products. Between 1970 and 1994, global wood consumption increased by 36%, according to the FAO, and the demand is likely to continue at roughly the same rate. As markets demand more, developing countries use their forests to power economic growth just as industrialized countries did a century ago. The forest clearance rate in Thailand, where the amount of wooded land fell from 53% of the country's area in 1961 to 29% in 1986, is about that of Pennsylvania early in this century.

Despite all the international attention, industrialized countries have not lived up to their pledges of support for forest conservation efforts, and the deforestation juggernaut advances, with effects ranging in scale from local changes in climatic and disease patterns to global climate change and biodiversity loss.

Infectious Diseases

There are many factors at work in emerging infectious diseases, but perhaps one of the most potent is deforestation, which changes vector habitats and, at the same time, brings large numbers of people into closer contact with those vectors. The most comprehensive global survey of the effects of deforestation on infectious disease rates remains a 1993 article published in a supplement to volume 106 of the journal *Parasitology*, written by researchers at the Liverpool School of Tropical Medicine (LSTM). For this article, authors J.F. Walsh, D.H. Molyneux, and M.H. Birley sifted through research on arboviruses, malaria, Chagas disease, leishmaniasis, loiasis, lymphatic filariasis, onchocerciasis, and schistosomiasis. In several cases, they found that deforestation reduced a disease's prevalence and distribution, as it appears with loiasis, a disease transmitted by horseflies that Walsh and colleagues estimate affects 2–13 million people throughout West Africa. There, deforestation destroyed the forest mud habitat where the horseflies bred. As the horseflies died off, the disease was eradicated. And in Tanzania, studies showed that deforestation was linked to the decline of onchocerciasis, or river blindness, a leading infectious cause of blindness in Africa that is spread by blackflies. Forest clearance eradicated the vegetative cover the flies depend on.

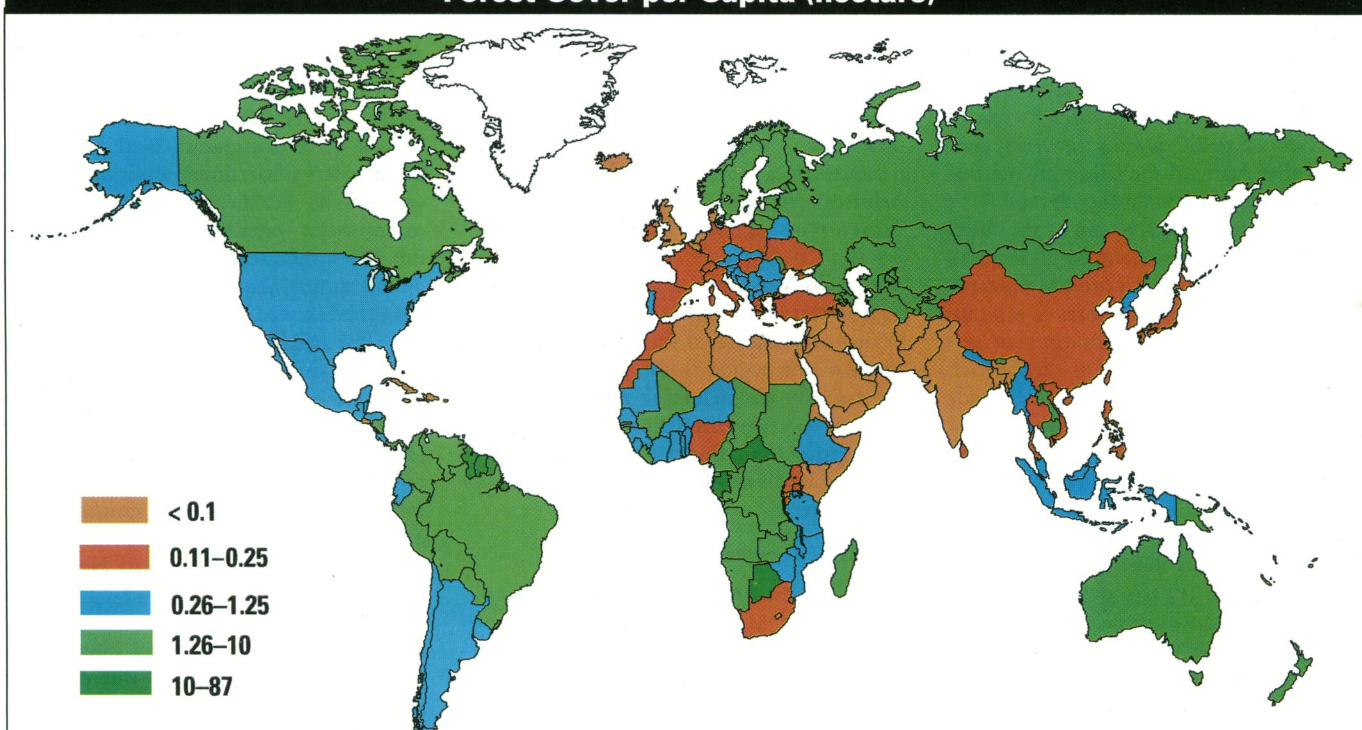
In most cases, however, deforestation was associated with an increase in disease. While malaria remains endemic in many parts of Africa and Latin America regardless of forest cover, the authors of the *Parasitology* article traced its rise elsewhere, especially in parts of Southeast Asia and Amazonia, where workers migrating into a logging area have experienced a large increase in malaria rates and a shift in the dominant vector, according to the *Parasitology* article. For example, in Thailand, removal of natural forest and the planting of coffee and rubber plantations have reportedly caused a decline in the *Anopheles dirus* type of mosquito, which requires heavy shade, and a rise in the *Anopheles minimus*, which prefers more open habitats. Research from the Peruvian Amazon showed that exposure to deforestation was the most significant risk factor in contracting leishmaniasis, which is transmitted by phlebotomine sandfly species. And, although the expansion in the range of schistosomiasis, which by 1990 affected 200 million people, appears to be related to hydro-electric dam projects, studies have linked the spread of at least one of the disease's causative organisms, *Schistosoma haematobium*, to deforestation.

Besides changes in the ecology of a disease vector and its options for hosts, deforestation can cause significant changes in local climate that effect the spread of disease. Removing forest vegetation usually reduces moisture held by the vegetation, and the loss of shade raises ground temperatures. In some highland areas of East Africa, such changes have raised temperatures enough to permit malarial mosquitoes to survive at higher elevations than they normally could.

At the watershed level, loss of forest cover can promote disease downstream. In the July-September 1997 issue of *Emerging Infectious Diseases,* researchers from the University of Alabama at Birmingham and the CDC recently reported a significant rise in hookworm infections in Haiti, where the disease was not previously common. Their longitudinal study of risk factors found that hookworm infection among children rose from zero to 12–15% between 1990 and 1996, although environmental factors such as rainfall and temperature remained relatively unchanged from earlier years. They traced the rise to flooding due to heavy siltation and runoff from the denuded watershed, combined with a breakdown of river channel maintenance following the country's political upheaval in 1990.

Deforestation brings social disruptions

Forest Cover per Capita (hectare)



Source: CIFOR. 1996 Annual Report. Jakarta:Center for International Forestry Research, 1996;46. Original data from the World Conservation Monitoring Centre.

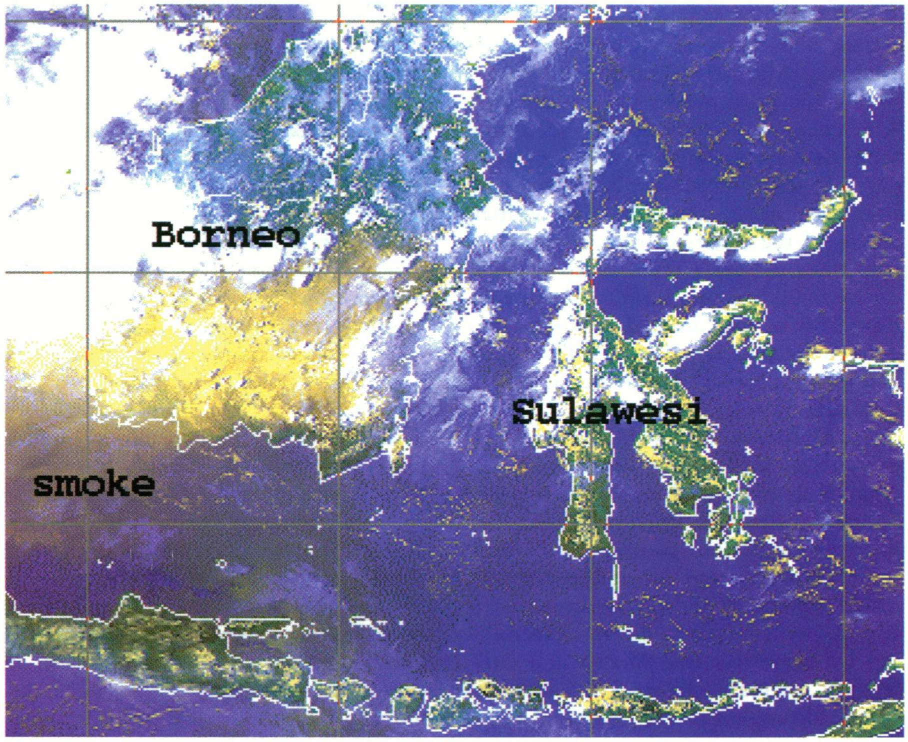
as profound as its ecological changes. For example, Joel Breman, deputy director of the division of international training and research at the Fogarty International Center of the National Institutes of Health, observed the effects of logging operations on West African society. In addition to the occupational hazards experienced by logging workers, deforestation brought intense social pressures as a result of the relocation of whole communities to new sites. Together, these factors created adverse effects that Breman says are often not well documented, including depression, violence, and alcohol abuse.

Emissions and Climate Change

Besides its direct impacts on the spread of disease, deforestation can cause polluting emissions and the loss of ecosystem functions that filter toxins from air, soils and water.This fall, widespread fires in Indonesia blanketed much of Southeast Asia with a thick haze. September media accounts reported that the pollution caused 35,000 people in Indonesia and 23,000 in Malaysia to seek treatment for respiratory problems. According to reports by the Associated Press, from Indonesia's eastern islands westward to southern Thailand, air pollutant indices, which measure sulfur dioxide, carbon dioxide, nitrous oxide, lead, and dust particles, soared. On a scale where 100 is considered unhealthy, Kuching, Malaysia, registered 839. In Singapore the daily index repeatedly passed 160.

The fires, which blackened 300,000 ha on the islands of Borneo and Sumatra, were initially blamed on a drought related to El Niño. Satellite photos, however, confirmed that many of the fires were deliberately set to clear forest and scrub land. "We are seeing a scramble for land at the forest frontier," said a statement by Indonesia's Center for International Forestry Research (CIFOR), which views the fires as a symptom of inadequate land management systems and policies. A layer of carbon-rich peat underlying many of the fire sites made the haze especially unhealthy. Burning peat "releases particulate matter and sulphur and nitrous oxides, which make the haze a greater threat to human health," according to the CIFOR statement.

Deforestation's most famous emission is carbon dioxide, the prime offender among greenhouse gases. In 1995, the Intergovernmental Panel on Climate Change (IPCC), an international group of scientists established in 1988 by the World Meterological Organization and the WHO, confirmed that carbon dioxide is the primary greenhouse gas and that greenhouse



Source: National Oceanic and Atmospheric Administration at http://goeship.wwb.noaa.gov/SPECIAL/FIRES/INDONESIA/avh1001e.gif

Deliberate chaos. Satellite photos show raging fires in Indonesia which were set to clearcut forests.

gases together could raise global temperatures by as much as 3°C in the next century. Deforestation is responsible for about 25% of net annual releases of carbon dioxide into the atmosphere and also reduces the capacity of forests to absorb greenhouse gas emissions. Resulting health consequences include changing patterns of disease transmission and host–vector relationships, increases in food- and water-related diseases, and a rise in cardiovascular and respiratory problems. In addition, the intense heat from forest-clearning fires releases mercury gas that is stored in wood, leaves, roots, and soil. In a letter published in the 28 April 1994 issue of *Nature*, Marcello Veiga and coauthors from the University of British Columbia in Vancouver calculated that deforestation in the Amazon region is also a major emitter of mercury gas, releasing more than 710 tons of mercury annually in a form more dangerous than the waterborne mercury released by all of the region's small mining operations.

Valuing Forests

Still, economics is a powerful force. Efforts to stop deforestation must address the economic incentives behind it and somehow assign values to forests' previously unquantified benefits of biodiversity, potential medicines, and climate mitigation. Policy planners can weigh options with price tags more easily than those without. Such valuation is starting to happen through accounting exercises and increasing use of conservation and reforestation as tools of environmental clean-up.

In the spring of 1997, the city of New York found a clear economic rationale for exploring watershed acquisition as a cost-effective substitute for building water treatment facilities. Forest land represents one of the cleanest land-use options affecting surface water (see graph). New York faced the prospect of declining water quality and spending $6–8 billion, plus operating costs, to construct water treatment facilities. So the city announced it would spend $1.5 billion to buy about 32,400 ha of Catskill watershed instead, as a preventive course.

The neighboring state of New Jersey adopted this strategy years ago. Since 1961, New Jersey has purchased more than 153,000 ha of watershed lands crucial for preserving water quality. "That's the way to go," says Thomas Lovejoy, the Smithsonian Institution's counselor on biodiversity and environmental affairs, who recalls the good taste of New York City water from his childhood. "They save so much money by letting nature do it." But such purchases are not a simple solution to implement. They require elaborate negotiation and coordination among many jurisdictions and residents, many of whom resent the water demands of distant cities like New York.

On an epic scale, Robert Costanza, a professor of ecological economics at the University of Maryland–College Park, and 12 colleagues calculated the total value of the world's ecosystem services and contents. These calculations were published in the 15 May 1997 issue of *Nature*. The researchers put the value of waste treatment services provided by forests—including water purification, pollution control, and detoxification—at $87 per ha. Worldwide, this totaled more than $422 billion, yet still ranked only as the third most valuable forest service behind climate regulation and erosion control.

Such calculations are more than academic exercises, many say. *Climate Change and Human Health*, a 1996 report prepared jointly by the WHO, the World Meteorological Organization, and the United Nations Environment Programme, champions the importance of such studies because, the report says, "they seek a sustainable balance of values, interests, and behaviors" on which societies can base their choices for policies and action.

Reforestation for Global Cleanup

The IPCC's findings about climate change have set international initiatives in motion. The first meeting of parties to the United Nations Framework Convention on Climate Change (FCCC) in 1995 launched a four-year pilot phase of joint implementation projects in which private utilities in industrialized countries and other greenhouse-gas emitters can offset their high emissions of greenhouse gases by trading so-called "carbon credits" with countries with low emissions. For example, utilities may pay for carbon-sequestration projects, including reforestation, and earn credits against their own emissions.

This phase necessitates the enormous task of quantitatively measuring carbon storage in both natural forests and man-made forest plantations, a task that is complicated by the biological dynamics of tree growth and the fact that different tree species sequester carbon at different rates. But it could also make commercial logging less damaging.

In Malaysia, CIFOR and its research partners are using financial incentives based on carbon emission offsets to test reduced-impact logging methods that could make commercial forestry harvests more efficient and more environmentally sound. CIFOR studies show that such methods, including selective felling that leaves more vegetation in place and use of equipment that minimizes soil compaction, erosion, and vegetation loss, could immediately improve the local and global environment. Assuming results similar to CIFOR's, a shift to reduced-impact logging techniques could reduce soil damage at a logging site by about 25% and increase the site's carbon storage benefits by roughly 50%, according to Dennis Dykstra, deputy director-general for research at CIFOR. If just 20% of all tropical forestry operations adopted those methods, he says, it could reduce soil damage in tropical forests worldwide by an average of 5% and increase carbon storage benefits by 10%. Debate continues over the equity of joint implementation and the difficulties of monitoring, but such a plan could significantly boost incentives for a less destructive forest industry.

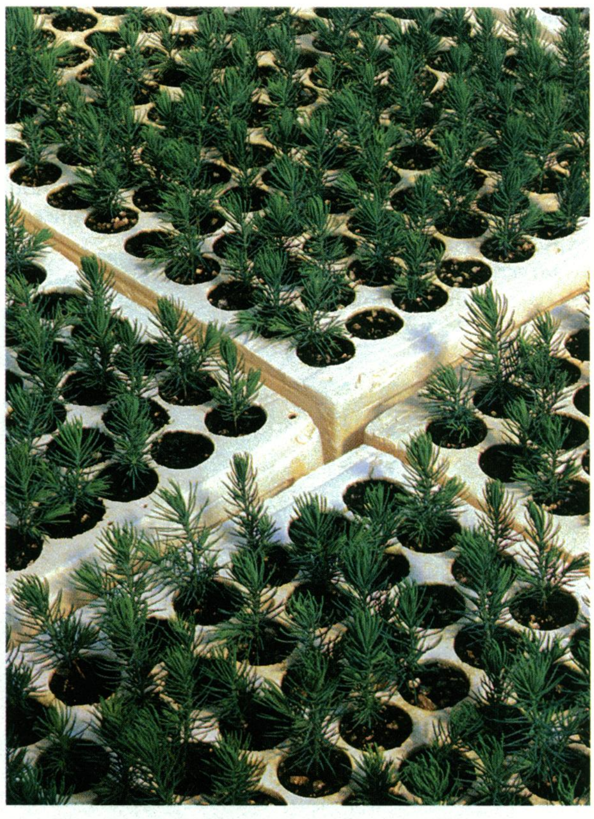
Reforestation can also be controversial. Some environmentalists claim that the carbon storage benefits of forest plantations—which generally are commercial plantings of exotic species for fast timber growth, and are often kept free of undergrowth and wildlife—mask a huge loss to biodiversity, as such plantations are much narrower in biodiversity and ecosystem function than the forests they replace. Also, because such plantations are often large, commercial operations that marginalize the claims of poor communities, plantations often exacerbate social inequalities. CIFOR director Jeffrey Sayer and coauthors of a May 1997 CIIFOR-published paper acknowledge that "plantations generally provide fewer environmental benefits than natural forests, . . . [but they] nevertheless are a better environmental option than most other land uses" to which the forests would likely be converted. Plantations, notes Sayer, can reduce logging pressures on large areas of natural forest by meeting the demand for timber and through involvement of nearby communities, and foster economic growth and employment in poor tropical countries, which can in turn improve health conditions among those populations. "Plantation forestry should be considered as complementary to the management of natural forests," Sayer writes, "and not as a substitute."

Plantations: Cure or Added Risk?

One factor rarely considered in reforestation projects is the potential to spread human disease. When asked whether forestry planners have ever approached health experts about the possible health risks of plantations, Molyneux says, "Good heavens, no. No chance. This is really a major problem but you don't see any change in policy. The communication between the health sector and the agriculture, forest, and agroforestry sectors is practically nonexistent."

Molyneux and his coauthors cited cases where reforestation opened the door to new epidemics among nearby human populations. In Trinidad, for example, *Erythrina* trees planted as shade trees for cocoa plantations created a habitat for malarial mosquitoes and caused an epidemic that was relieved only when the trees were removed.

Health effects of reforestation efforts are the subject of current research in Thailand sponsored by the Task Force on Tropical Diseases and the Environment, led by the WHO. In the Kanchanaburi district of western Thailand, recent studies by researchers from Mahidol University, the Thailand Malaria Control Program, the U.S. Armed Forces Research Unit for Medical Sciences, and the Asian Institute of Management show that rubber plantations



A questionable solution. Although reforestation through plantations may provide some measure of environmental remedy, problems inherent in their use range from loss of biodiversity to fostering of social inequalities in poor communities.

and orchards provide a breeding habitat for the most virulent malaria vector in Southeast Asia, *Anopheles dirus*. The plantations are basically reintroducing malaria, which had declined when the area's natural forest was cleared.

Forest management textbooks, as well as guidelines published by the International Tropical Timber Organization, based in Japan, warn against introducing exotic tree species without trial experiments, and caution that plantations consisting of only a few species are vulnerable to outbreaks of pests and disease. Nevertheless, species trials—not to mention assessments of potential pest problems or human health risks—require years and resources that forest managers rarely find in their budgets.

In cases where establishing plantations results in an outbreak, the cost of poor communication among the sectors tends to be borne by the health sector, while the agriculture and forestry sectors gain the economic benefits of the plantations' production. As the WHO task force notes, this imbalance will continue until health officials convince producers to invest in preventive or control measures.

Food Security and Nutrition

Deforestation is causing a tremendous loss of biological diversity worldwide. The FAO states that over the next 50 years, deforestation will rank as the single greatest cause of species loss. The consequences of this loss, particularly in terms of lost potential medicines from tropical rain forests and the dynamics of associated human disease, are explored in a new book, *Biodiversity and Human Health*, a compilation of data from a 1995 conference of the same name that was co-sponsored by the National Institutes of Health, the National Science Foundation, and others.

Perhaps the most endangered health benefits of forests are those that have sustained rural populations for centuries: food and medicines. The FAO has found that poor households in particular rely on forests for foods such as fruits, leaves, seeds, nuts, mushrooms, and insects, which provide essential proteins. When forests are cleared, these products disappear along with the forest's soil maintenance properties. As crop yields deteriorate with erosion and local climate change, the loss of traditional forest foods and medicines amplifies the impoverishing effect. "The contribution of forests and trees to food security should not be underestimated," says David Harcharik, the FAO's assistant director general for forestry.

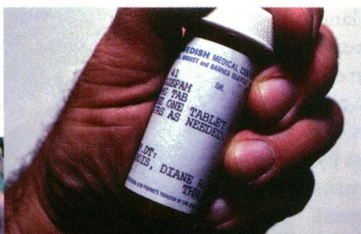
These traditional forest products, however, may also provide an opportunity for forest conservation. At least 150 non-timber forest products are significant in international trade, with a total estimated value of $11.1 billion, according to the FAO. Community-level enterprises such as food processing, harvesting of medicinal plants, manufacture of crafts, and ecotourism can form an economic basis for maintaining the forest ecosystem. For example, a worldwide boom in herbal medicines has fostered creation of medicinal plant reserves; in places, it has also caused depletion of these species from natural forests (*EHP* 104:924–928). Communities near forests need access to technical expertise to gauge the biological impacts of harvests. If harvests can be managed at a biologically sustainable level, those communities can maintain the forests' health benefits and at the same time gain value-added income.

Alongside these opportunities comes research to explore the potential of forest species in modern medicine. Ethnobotany, the scientific study of plants and their uses in traditional societies, has experienced a resurgence since the mid-1980s, following several decades of decline (*EHP* 102:268–269). In a chapter of *Biodiversity and Human Health*, Paul Alan Cox, an ethnobotanist and professor of botany at Brigham Young University, describes his research on Samoa with local healers. That collaboration, supported by the NCI, identified antiviral properties of a local plant, *Homalanthus nutans*, and led to the isolation of the drug prostratin, which the NCI has pursued as an anti-AIDS therapy. Cox later played a role in preserving forests on Samoa for further medicinal use.

Modern bioassay techniques enable broader-based inventories that quickly screen plants and insects in biologically rich tropical forests for potential medicinal compounds. Estimates of modern medicines originating from botanical sources range from 25% to over 50%, and that's from a very narrow selection of species. A vast majority of forest species have yet to be identified, much less screened for potential medicines.

Bioremediation for Local Cleanup

Another way that forest plants provide health benefits is by cleaning up toxic deposits at polluted sites. Bioremediation is emerging as a cost-effective way of managing some types of clean-up, particularly for water and soils. In the state of Washington, poplar trees are being tested as an option for cleaning up the state's 10,000 sites contaminated with trichloroethylene (TCE), a common groundwater pollutant



More than lumber. Some of the most endangered benefits of forests are not the timber, but food products such as fruits, nuts, and mushrooms and the myriad potential drugs from tropical rainforests.

once used in dry-cleaning. Milton P. Gordon, professor of biochemistry at the University of Washington in Seattle, started growing poplars in sealed containers with TCE concentrations of 50–70 parts per million. The trees absorbed more than 90% of the pollutant. Now Gordon and colleagues are testing the trees' absorption abilities at field sites near Tacoma, Washington, and Medford, Oregon. At Medford, several hundred poplar trees were planted at the spot where a tanker spilled methyl chloroform. "It's working pretty well," says Gordon. The trees appear to mineralize the pollutant, leaving no toxic residue. Larger-scale tests are starting in Hawaii.

Researchers at the U.S. Department of Agriculture's Environmental Chemistry Laboratory in Beltsville, Maryland are less sanguine about trees' prospects for absorbing heavy metals. Rufus Chaney, a biochemist with the U.S. Department of Agriculture's Agricultural Research Service, has found that the perennial Alpine pennycress (*Thlaspi caerulescens*) can absorb zinc at an incredible 25,000 mg of zinc per kg of plant. Forest plants, however, present some difficulties. There are forest species that are metal hyperaccumulators, says Chaney, but "unfortunately, the metal goes into the leaves, not the wood." This means the pollutant ends up on the ground surface, not contained in a wood product. "Nobody has found a way to get it into the trunk," says Chaney.

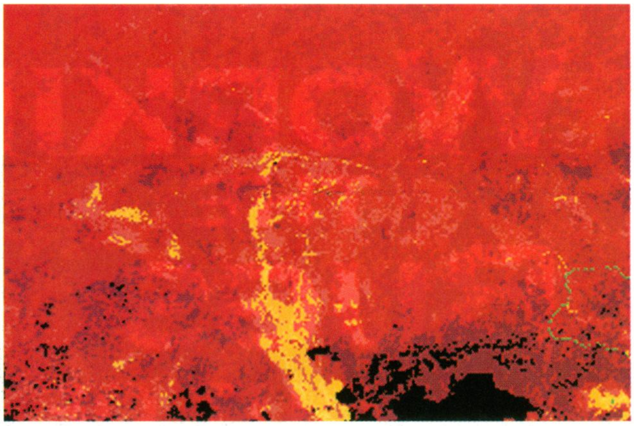
New Tools

Protecting forest resources and thus forest benefits, say the authors of *Climate Change and Human Health*, calls for "primary environmental care," analogous to primary health care. Primary environmental care, they explain, is "community-level activity, aimed at preserving the environmental resources on which the community in question depends."

Lovejoy adds a slightly different perspective. "What we really need to be doing is managing large areas of landscape as ecosystems," he says. This involves a move "from isolated decision-making to a more consultative form."

New methods for mapping the environment, such as geographic information system (GIS) technology, are giving resource managers and public health experts a basis for working together. This collaboration is important, says Joshua Rosenthal, director of the NIH's biodiversity program, because epidemiologists and ecologists have traditionally not worked together. Researchers need to identify patterns that may relate the biological environment to the dynamics of human disease. "There are almost certainly many types of disease–environment interactions that we will not understand without multidisciplinary research," says Rosenthal.

When Madeleine Thomson, a field entomologist and eco-epidemiologist based at the LSTM, visited Sudan in 1991 with fellow LSTM professor R.W. Ashford, she found a civil war and probably the worst epidemic of visceral leishmaniasis in history. Since 1984, the disease, spread by a sandfly vector, has caused over 100,000 deaths in the western Upper Nile area of southern Sudan—about half of the local population. During their visit, Thomson and Ashford noticed that the trees, predominantly *Acacia seyal* and *Balanites aegyptiaca*, were all of uniform age. "In fact, I recall someone pointed out an old tree [as exceptional]," says Thomson.



Madeleine Thomson, MALSAT

The Sudd from space. A MALSAT image shows changes in vegetation in the Sudd area of southern Sudan, where an epidemic of visceral leishmaniasis is occurring. The swamp areas (shaped like a yellow "y"), which are the breeding ground for the disease's vector, were created by deforestation and subsequent reforestation.

This led them to question the relationship between the woodlands and the disease. Residents confirmed that the Nile floods in the 1960s, following a rise in the level of Lake Victoria, had killed forests throughout that region. As the woodlands returned, they created a habitat in which the sandfly population multiplied. By mapping the *Acacia–Balanites* woodlands and the region's basaltic "black cotton" soils using remote-sensing images, Thomson and her colleagues at the MALSAT Research Group are giving Sudanese health workers a way to focus their control efforts for visceral leishmaniasis.

MALSAT, an acronym for environmental information systems for malaria, an eco-epidemiological project at the LSTM, shows how national health planners and international emergency aid workers can use low-cost remote sensing images, interpreting them using factors relevant to vector-borne disease, to predict disease hot spots. MALSAT compiles images incorporating indices of rainfall, surface temperature, and vegetation, and relates these to the environmental factors associated with the timing and location of disease outbreaks. Current studies are adapting indices for identifying areas vulnerable to epidemics of malaria, meningoccal meningitis, and visceral leishmaniasis.

"The timing is right," says Thomson of MALSAT's efforts. Health officials in Africa have access to computers now, GIS programs have reached a new level of user-friendliness, and many of the satellite data are being collected in-country by local meteorological stations for agricultural purposes. MALSAT is working with health officials to develop early warning systems to identify areas where ecological conditions suggest risk of crop failure or disease. In the case of visceral leishmaniasis, remote sensing is the only way to assess ecological–epidemiological risk areas, since the data are simply not otherwise accessible due to the civil war.

Thomson and coauthors wrote a chapter for a 1995 book, *GIS and the Environment*, in which they argue that it is up to health officials to take advantage of new tools like remote sensing. Remote sensing experts are eager to apply their powerful new skills to new problems. "It is up to the health community to identify and demand specific types of information," says Thomson.

In this century, forests around the world have come under heavy pressure to make way for people, often at the cost of functions that affect human health: filtration of impurities from water, soil, and air; provision of food and nutrition; and maintenance of the global climate's chemical balance. As forests' former functions are rediscovered through efforts in bioremediation, watershed purchases, and greater collaborations between epidemiologists and ecologists, a clearer consensus on forests' health values may emerge.

David Taylor